number of prisms, (2) small diameters of the prisms as compared with those of the Giant's Causeway and the Devil's Tower (the latter attaining as much as six feet) (3) no apparent change in texture from the center to the periphery of the prisms, (4) great irregularity of faces on the prisms, and (5) relative scarcity of convexity and concavity in cross-jointing. The amygdaloidal structure suggests that the diabase is a sheet which was extruded towards the close of Upper Triassic (Keuper) time in Virginia.

PALEONTOLOGY.—*Five new genera of Carboniferous Crinoidea Inadunata.*[1] EDWIN KIRK, U. S. Geological Survey.

Owing to a series of misunderstandings, mischances, and mistakes the genera *Zeacrinus*, *Woodocrinus*, *Pachylocrinus*, *Scaphiocrinus*, and *Graphiocrinus* have been involved in a maze of nomenclatorial difficulties. Springer (1911) was well on the way toward clearing up the situation in part and did extricate *Pachylocrinus* from the confusion, which was his immediate purpose. He suggested the separation of one group of species under a new genus, but unfortunately did not give it a name, referring the species to *Woodocrinus*? instead. Subsequently Springer (1926) threw typical members of this latter group back into *Zeacrinus*, under which they had first been described in the main. This action again made *Zeacrinus* a catch-all for Carboniferous crinoids whose "only stable character," according to Springer (1926, p. 78), "is the heterotomous arm-branching, with mostly uniserial, short and distally quadrangular brachials." It is only fair to state that this paper was written by Springer under most adverse conditions, with seriously impaired health and without access to specimens and limited access to literature. It seems probable that he overlooked his own conclusions of 1911, for otherwise he certainly would have mentioned them and given reasons for their abandonment.

In the present paper a number of species will be considered, most of which have been referred to *Zeacrinus* at one time or other, chiefly by Wachsmuth and Springer and by Springer. To these are added some species that seem referable to the genera here described. It is not my purpose at this time properly to assign to their respective genera the large number of species that at one time or other have been referred erroneously to *Zeacrinus*. In earlier days Meek considered *Zeacrinus* a probable synonym of *Hydreionocrinus*. Meek and Worthen, Shumard, and Lyon considered the possibility that *Zea-*

[1] Published by permission of the Director, Geological Survey, United States Department of the Interior. Received Feb. 1, 1938.

crinus and *Graphiocrinus* were synonyms. Later, Miller and Gurley's species of *Zeacrinus* were about equally divided between *Zeacrinus* and *Phanocrinus*. Some species referred to *Zeacrinus* will fall into *Pachylocrinus*. The reference of many of the described species to their respective genera can best be made after the genera involved are clearly defined, each with a nucleus of characteristic species referred to it. Short of a monographic study of the Inadunata, a treatment such as that given here seems the most feasible method of attack on an admittedly difficult problem. The group more or less centering about *Zeacrinus* was chosen because it seemed to be the one most involved in nomenclatorial difficulties, and the species of which historically were the most uncertain of placement.

An attempt is here made to create generic groups on the basis of genetic relationship and evolutionary trends. In the Carboniferous thousands of specimens of Inadunata are available for study in the collections, representing a long and not greatly interrupted period of geologic time. It should then be possible to segregate lines of descent and express the results in terms of classification. Undue emphasis on one structural feature, such as the ventral sac or the plates of the posterior interradius, is unfortunate. It has been found that combinations of characters, with varying weights given to different factors dependent on the stage in phylogeny, give the most satisfactory results. Such genera do not lend themselves well to placement in analytical charts, but this may be an advantage rather than otherwise. Such genera, however, if properly made, possess the merit of having definite stratigraphic value and can be used intelligibly in the discussion of biologic problems. A discussion of the criteria used in discriminating the genera would be desirable but in itself would prove to be a work of considerable size. The criteria after all are essentially those used by critical workers in the past. In the brief generic diagnosis an attempt is made to present the norm for the genus, with brief indications of permissible variants in structure.

In the lists of species the dates and authors' names alone are given for bibliographic reference, and the complete citations may be found by referring to the bibliography at the end of the paper. No attempt is here made to indicate synonymy of species or quote synonymies hitherto made by authors. Either would be of little value at this time. I have had access to the types of the majority of the species, or reasonably authentic specimens identified by Wachsmuth. In the case of several of the species illustrations are wanting and in others are of poor quality. The types of some of these species have ap-

parently been lost. Many species have been based on immature individuals, and these are particularly difficult to place. Horizons and localities are quoted as given in the original descriptions. Amended citations of stratigraphic horizons are given in parentheses, where available and when known to differ from the original text.

The genotypes of five of the six genera discussed in this paper, *Alcimocrinus*, *Cercidocrinus*, *Eratocrinus*, *Zeacrinus*, and *Linocrinus* are very fully illustrated by Springer (1926). For the illustration of the genotype of *Adinocrinus* one must refer to the original description of Wachsmuth and Springer.

Zeacrinus Troost

Zeaecrinites, nom. nud., Troost, p. 419, 1849; p. 61, 1850.
Zeacrinus Troost, in Hall, p. 544, 1858.
Genotype.—Zeacrinus magnoliaeformis Troost.
Generic diagnosis.—
Crown. Ovoid.
Dorsal cup. Basin-shaped with deeply invaginated base.
IBB. Small, forming bottom of basal pit, covered by column.
BB. Variable in size and shape but typically elongate, lanceolate, taking part in the basal pit.
Post B, when in contact with anal x, greatly elongated.
RR. Radial facet extends full width of R, suture not gaping. Articulating face at high angle.
Anal plates. Variable in size, shape, and arrangement. Typically three plates in cup. Anal x in contact with post B, meeting it on a narrow oblique face. RA penetrates deeply between post B and R post B, sometimes completely separating them. RA meets post B laterally and r post B on a very narrow face. In later phylogenetic stages the anal plates tend to migrate out of the cup. RT sometimes may do so. Anal x may lose contact with post B, its position being taken by RA, which in turn separates from post B.
IBr. One or two in anterior radius. One in other rays.
Arms. Endotomous. Rami laterally appressed, stout, with slightly convex backs. Br quadrangular.
Ventral sac. Pyramidal, with broad base.
Characteristic species of the genus.—

Zeacrinus magnoliaeformis Troost

Zeaecrinites magnoliiformis, nom. nud., Troost, p. 419, 1849.
Zeaecrinites magnoliaeformis, nom. nud., Troost, p. 61, 1850.
Zeacrinus magnoliaeformis Troost, in Hall, p. 544, 1858.
Zeacrinus magnoliaeformis Springer, p. 81, pl. 22, figs. 4–11, 1926.

Geologic and geographic distribution.—Zeacrinus as known is widely distributed in rocks of upper Mississippian age. In the United States it is one of the most characteristic crinoids of the Chester group. In Europe typical species of the genus are known in beds of equivalent age in England and Scotland.

Relationships.—I conceive the ancestor of *Zeacrinus* to be an undescribed genus, the earliest known species of which is found in the Keokuk. The genus carries on in the Borden of Indiana, the Warsaw of the Mississippi Valley, and the St. Louis of the same region. The early history of *Zeacrinus* proper seems to lie in the gap between the St. Louis and Chester. Forms referable to *Zeacrinus* may be expected in the Pennsylvanian as the genetic line continued to the Permian, *Paraburs acrinus* of this age differing little from *Zeacrinus* other than in the structure of the posterior interradius.

Adinocrinus, n. gen.

Genotype.—Zeacrinus nodosus Wachsmuth and Springer.

Generic diagnosis.—

Crown. Expanding slightly to level of II A x, then more rapidly to level of III A x, then curving inward.

Dorsal cup. Depressed basin-shaped, small in comparison with the size of the crown, sharply pentagonal in outline.

IBB. In bottom of central depression, covered by column or slightly projecting beyond it.

BB. Relatively very small, typically showing as triangles separated by the RR, which in such case contact with the IBB. Post B larger than the others. In one specimen (young?) three of the BB meet laterally, but by very narrow faces.

RR. Proportionally very large. Radial facet extends full width of R. Suture gaping. Articulating face at high angle and very deep.

Anal plates. RA long and narrow, sometimes touching, sometimes not touching r post B; meeting post B on long lateral face. Anal x usually high in cup, separated from post B and lying in line with RA, on which it rests. RT resting on sloping upper right shoulder of anal x and either on the truncated upper face of RA or a narrow facet on upper left shoulder of post R.

IBr. Five in anterior radius in the three specimens seen. One in all other radii. IBr_1 of ant. R very high with oblique upper face.

Arms. Isotomous, with two divisions above the main dichotom. The rami are very stout, with rounded backs and composed for the most part of quadrangular Br. Below the finials many of the Br show a pronounced taper, but in all cases the Br extend the full width of the ramus. All axillaries are nodose, and the proximal Br of each series is larger than the succeeding Br and is strongly convex to nodose. This applies to all three species of which the arms are known. Below the III A x there are processes on the lateral margins of the Br which interlock with similar processes of the Br of the juxtaposed ramus.

Ventral sac. Unknown.

Characteristic species of the genus.—

Adinocrinus compactilis (Worthen) n. comb.

Zeacrinus compactilis Worthen, in Meek and Worthen, p. 536, pl. 21, figs. 5a, b, 1873. "Lower Carboniferous, Cumberland County, Kentucky." (Figured on plate labeled "Chester Beds."); Wachsmuth and Springer, p. 128 (351), 1880; Wachsmuth and Springer, p. 243 (167), 1886.

Adinocrinus nodosus (Wachsmuth and Springer), n. comb.

Zeacrinus nodosus Wachsmuth and Springer, p. 243 (167), pl. 6, fig. 9; pl. 9, fig. 3, 1886. "Keokuk limestone." Whites Creek Springs, near Nashville, Tenn., (New Providence equivalent).

Geologic and geographic distribution.—The genus *Adinocrinus* is known only from the New Providence formation, lower Mississippian, of Kentucky and an approximately equivalent horizon at Whites Creek Springs, near Nashville, Tenn.

Relationships.—With a dorsal cup resembling *Zeacrinus* near the end of its line, and with arms of such extraordinary character, one is at a loss to indicate relationships or point out any genus which might serve as an antecedent type. I do not think *Adinocrinus* should be placed in the same family as *Zeacrinus*. The pentagonal cup and the narrow posterior interradius were probably induced by the unusually heavy arms. The narrow posterior interradius combined with the upward migration of anal plates, a tendency common to many Inadunate lines, has given us a cup strikingly like *Zeacrinus* of the later type. There all resemblance to *Zeacrinus* and its allies ceases. If we lack an antecedent type there is a later type that has some of the outstanding peculiarities of *Adinocrinus*. *Protencrinus* Jaekel (1918) from rocks of Pennsylvanian age in Russia has similar small subtriangular BB separated by the RR, which extend down to the IBB. Very heavy arms with cuneate nodose Br also favor the relationship. In *Protencrinus* the arms remain simple above the first dichotom, but this is permissible, as a reduction in the number of rami can be demonstrated in other crinoid lines. In *Protencrinus* the anal plates have passed entirely out of the cup, which would be expected in a descendant of *Adinocrinus*. A dorsal cup from the Permian of Timor has been referred to *Protencrinus* by Wanner (1924), and a dorsal cup from the Viséan of Germany has been identified as *Protencrinus* by Schmidt (1930).

Alcimocrinus, n. gen.

Genotype.—Zeacrinus girtyi Springer.

Generic diagnosis.—

Crown. Subcylindrical, slightly spreading distad.

Dorsal cup. Depressed basin-shaped, invaginated at base.

IBB. Small, in central depression, concealed by column.

BB. Subequal, relatively large.

RR. Radial facet extending full width of R, suture not gaping.

Anal plates. RA rests subequally on sloping shoulders of post and r post BB, not penetrating deeply between them. Anal x rests on the wide, horizontal distal face of post B.

IBr. Two in all rays, but more might be expected in ant. R.

Arms. Endotomous. The outer portion of the half-ray is essentially an arm-trunk, very stout and reminding one of certain Camerate types, such as *Ctenocrinus*. The rami given off to the inner side of the ray are more numerous than in any genus of this group and resemble ramules more than true arm branches. The Br of the main arm-trunks are quadrangular in the main but with interspersed cuneate ossicles. The Br of the side rami are quadrangular.

Ventral sac. The ventral sac is long and club-shaped, extending beyond the tips of the arms.

Characteristic species of the genus.—

Alcimocrinus girtyi (Springer), n. comb.

Zeacrinus girtyi Springer, p. 84, pl. 23, figs. 9, 9a, 1926. "Morrow formation of the basal Pennsylvanian; near Crittenden in northeastern Oklahoma." (Wapanucka limestone *fide* Ulrich.)

Geological and geographical distribution.—The only known species of the genus is found in the early Pennsylvanian (Morrow group) of Oklahoma.

Relationships.—*Alcimocrinus* differs from *Zeacrinus* in important respects. The dorsal cup, though depressed basin-shaped, has essentially the structure of the early Mississippian species here referred to *Eratocrinus*, as pointed out by Springer (1926, p. 85). The presence of two IBr in the rays other than ant. R is of importance in a type as late as this. The long club-shaped ventral sac is also reminiscent of *Eratocrinus*, though considerably longer than in that genus. The arms of *Alcimocrinus*, which are in effect arm-trunks with lateral ramules, differentiate the genus from any other known. *Parabursacrinus* Wanner of the Permian, which Wanner probably with justice derives from *Zeacrinus*, is essentially *Zeacrinus* as to arms and shape of crown. It is probable that *Alcimocrinus* lies outside the *Zeacrinus* line, and the two are to be derived from a common but fairly remote ancestor.

Cercidocrinus, n. gen.

Genotype.—*Poteriocrinus bursaeformis* White.

Generic diagnosis.—

Crown. Spreading gradually from base.

Dorsal cup. Turbinate, not invaginated at base.

IBB. Plainly visible in lateral view, relatively large.

BB. Subequal, of nearly same height as breadth.

RR. Radial facet the full breadth of the R, suture not gaping.

Anal plates. Three in cup, RA resting subequally on upper sloping shoulders of post and r post BB, x resting on horizontal wide truncated distal face of post B.

IBr. Three to four or more in ant. radius, one or two in other radii. A single IBr (other than in the ant. R) seems normal for Burlington time, though exceptions have been seen in single rays. In the Kinderhook one new species has two in all rays, except the anterior, which has seven.

Arms. Endotomous, long, rounded, sides not flattened, showing that the rami were not normally closely appressed. Br very low, quadrangular.

Ventral sac. Unknown.

Characteristic species of the genus.—

Cercidocrinus blairi (Miller and Gurley), n. comb.

Poteriocrinus blairi Miller and Gurley, p. 61, pl. 4, figs. 1, 2, 1895. "Burlington group, at Sedalia, Missouri."

Cercidocrinus bursaeformis (White), n. comb.

Poteriocrinus bursaeformis White, C. A., p. 10, 1862. "Lower division of the Burlington limestone, Burlington, Iowa."

Zeacrinus bursaeformis Wachsmuth and Springer, p. 128 (351), 1880.
Woodocrinus bursaeformis Wachsmuth and Springer, p. 242 (166), 1886.
Woodocrinus? bursaeformis Springer, p. 147, 1911.
N. Gen. bursaeformis Springer, p. 148, 1911.
Zeacrinus bursaeformis Springer, p. 79, pl. 21, fig. 1, 1926.

Cercidocrinis cirrifer (Laudon), n. comb.

Pachylocrinus cirrifer Laudon, p. 63, pl. 6, figs. 3, 4, 1933. "Gilmore City formation, Gilmore City, Iowa."

Cercidocrinus fimbria (Laudon), n. comb.

Pachylocrinus fimbria Laudon, p. 64, pl. 5, figs. 2, 3, 1933. "Gilmore City formation, Gilmore City, Iowa."

Cercidocrinus infrequens (Laudon and Beane), n. comb.

Zeacrinus infrequens Laudon and Beane, p. 257, pl. 17, figs. 11, 12, 1937. "Hampton formation, Le Grand, Iowa."

Cercidocrinus? sampsoni (Miller and Gurley), n. comb.

Poteriocrinus sampsoni Miller and Gurley, p. 65, pl. 4, figs. 9, 10, 1895. "Chouteau limestone at Sedalia, Missouri." (Dorsal cup only.)

Geological and geographic distribution.—*Cercidocrinus* is known only from the Kinderhook, Chouteau (?), and Burlington formations of Iowa and Missouri. It reached its maximum size in the lower Burlington, and this seems to have been its latest appearance. The maximum number of species has been found in the Kinderhook. In addition to those listed there are at least two additional new species from that horizon.

Relationships.—It is difficult to draw conclusions in regard to the interrelationships of *Cercidocrinus*. Lacking knowledge of its ontogeny or its Upper Devonian antecedents we can only attempt a placement according to our knowledge of the behavior of similar crinoid stocks. Its relationships seem to be nearest to forms commonly referred to *Pachylocrinus*.

In arm structure *Cercidocrinus* most nearly resembles *Eratocrinus* from which in its known characters its most notable difference is the turbinate dorsal cup and the prominent infrabasals. The crown has a different habit, spreading gradually distad, and the rami were not tightly appressed, as against the pyriform crown of *Eratocrinus* with its normally tightly packed rami. In the form of its dorsal cup *Cercidocrinus* approaches the British genus *Woodocrinus*, from which it chiefly differs in the structure of the arms, In *Woodocrinus* the arms are relatively short, stout, tapering rapidly distad. and isotomous in their division. *Coeliocrinus* differs chiefly from *Cercidocrinus* in its cuneate brachials, approaching a biserial condition. The ventral sac of *Cercidocrinus* being unknown, comparisons with that of *Coeliocrinus* are out of the question. The stress laid on the character of the distal portion of the ventral sac in classification among the Carboniferous Inadunata has been greatly overdone. Such structures should be made subsidiary and considered only as accessory features in evaluating a genus.

Eratocrinus, n. gen.

Genotype.—Zeacrinus elegans Hall.

Generic diagnosis.—

Crown. Elongate, usually with closely appressed arms, typically inverted pyriform in shape.

IBB. Small, concealed in basal pit.

BB. Of medium size, helping form the basal depression.

RR. Radial facet full width of radial, suture not gaping.

IBr. Two to five in the anterior radius, invariably one in other rays in all known species. [The two IBr in the r post R of fig. 2a, pl. 21 (Springer, 1926) are incorrect.]

Arms. Endotomous with slightly convex to rounded backs, composed of unusually low, quadrangular Br. Rami laterally appressed. Early species of *Eratocrinus* or young specimens may be expected to show isotomous arm divisions, with but one division above the main dichotom. Such structures are to be found in the lower Burlington *Eratocrinus pikensis* (Worthen) and *Eratocrinus scoparius* (Hall). In *E. scoparius* the arms usually bifurcate but once above the dichotom and are isotomous. Rays are to be found, however, where there is a second division above the dichotom, producing an endotomous structure. Judging from the figure of *E. pikensis*, a similar condition obtains in that species. It seems reasonably certain that the evolutionary stage preceding endotomy is isotomy, with a single division above the primary dichotom.

Anal plates. Three in cup. RA not penetrating deeply between post and r. post BB. Anal x resting on wide horizontal distal face of post. B.

Ventral sac. Moderately long, typically not reaching to tips of arms, club-shaped.

Column. Pentagonal with rounded angles, to round. Long, relatively stout cirri borne in whorls to within a short distance of the crown.

Characteristic species of the genus.—

Eratocrinus commaticus (Miller), n. comb.

Zeacrinus commaticus Miller, p. 36, pl. 5, figs. 10, 11, 1891. "Keokuk group, at Booneville, Cooper County, Missouri." (Warsaw).—Springer, p. 80, pl. 22, figs. 1–3a, 1926.

Eratocrinus coxanus (Worthen), n. comb.

Zeacrinus coxanus Worthen, p. 27, 1882.—Worthen, p. 302, pl. 28, fig. 1, 1883. "Upper beds of the Keokuk limestone, Hamilton, Illinois."

Woodocrinus coxanus Wachsmuth and Springer, p. 302 (226), 1886.

Eratocrinus elegans (Hall), n. comb.

Zeacrinus elegans Hall, p. 547, pl. 9, figs. 1, 2, 1858. "Burlington limestone, Burlington, Iowa."—Wachsmuth and Springer, p. 128 (351), 1880.

Woodocrinus elegans Wachsmuth and Springer, p. 242 (166), 1886.

Woodocrinus? *elegans* Springer, p. 147, 1911.

N. Gen. elegans Springer, p. 148, 1911.

Zeacrinus elegans Springer, p. 80, pl. 21, figs. 2–4, 1926.

Eratocrinus faggi (Rowley and Hare), n. comb.

Zeacrinus faggi Rowley and Hare, p. 103, pl. 2, fig. 20, 1891. "Upper Burlington limestone in Spencer Creek, 2 miles north of Curryville, Missouri."

Eratocrinus orbicularis (Hall), n. comb.

Scaphiocrinus orbicularis Hall, p. 311, 1861.—Hall, p. 7, 1861a. "Keokuk limestone, Keokuk, Iowa."—Hall, pl. 5, figs. 7–9, 1872.
Eupachycrinus? *orbicularis* Wachsmuth and Springer, p. 138 (361), 1880.
Eupachycrinus orbicularis Wachsmuth and Springer, p. 249 (173), 1886.
Zeacrinus orbicularis Wachsmuth and Springer, p. 334 (Index), 1886.—Worthen, p. 97, pl. 14, figs. 2, 2a, 1890.

Eratocrinus pikensis (Worthen), n. comb.

Zeacrinus pikensis Worthen, p. 29, 1882.—Worthen, p. 304, pl. 30, fig. 3, 1883. "Lower part of the Burlington limestone, Montezuma, Pike County, Illinois."
Scaphiocrinus pikensis Wachsmuth and Springer, p. 237 (161), 1886.

Eratocrinus ramosus (Hall), n. comb.

Zeacrinus ramosus Hall, p. 548, pl. 9, fig. 3, 1858. "Burlington limestone, Burlington, Iowa." (Upper Burlington).—Wachsmuth and Springer, p. 129, 1880.
Woodocrinus ramosus Wachsmuth and Springer, p. 242 (166), 1886.—Springer, p. 147, 1911.

Eratocrinus raymondi (Laudon and Beane), n. comb.

Pachylocrinus raymondi Laudon and Beane, p. 255, pl. 18, fig. 4, 1937. "Hampton formation, Timber Creek quarry, 2 miles west of Le Grand, Iowa."

Eratocrinus sacculus (White), n. comb.

Zeacrinus sacculus White, p. 12, 1862.
Zeacrinus sacculus var. *concinnus* White, p. 13, 1862. "Upper division of the Burlington limestone, Burlington, Iowa."

Eratocrinus salemensis (Miller and Gurley), n. comb.

Zeacrinus salemensis Miller and Gurley, p. 37, pl. 3, fig. 17, 1894. "Keokuk group at Salem, Indiana."

Eratocrinus scoparius (Hall), n. comb.

Zeacrinus scoparius Hall, p. 305, 1861.—Hall, p. 8, 1861a. "Burlington limestone, Burlington, Iowa." (Probably lower Burlington.)

Eratocrinus serratus (Meek and Worthen), n. comb.

Zeacrinus serratus Meek and Worthen, p. 151, 1869.—Meek and Worthen, p. 428, pl. 1, fig. 6, 1873. "Burlington group at Burlington, Iowa." (Upper Burlington).—Wachsmuth and Springer, p. 129 (352), 1880.
Woodocrinus serratus Wachsmuth and Springer, p. 242 (166), 1886.
Woodocrinus? *serratus* Springer, p. 147, 1911.
N. Gen. serratus Springer, p. 148, 1911.

Eratocrinus troostanus (Meek and Worthen), n. comb.

Zeacrinus troostanus Meek and Worthen, p. 390, 1861.—Meek and Worthen, p. 186, pl. 16, fig. 2, 1866. "Burlington limestone, Cedar Creek, Warren County, Illinois."—Wachsmuth and Springer, p. 129 (352), 1880.
Woodocrinus troostanus Wachsmuth and Springer, p. 242 (166), 1886.

Woodocrinus? *troostanus* Springer, p. 147, 1911.
N. Gen. troostanus Springer, p. 148, 1911.

Geographic and geologic ranges.—*Eratocrinus* as known has a geologic range in the lower Mississippian from the Kinderhook to the Warsaw inclusive. It is doubtful if this geologic range will be extended greatly by future finds. Geographically the genus is widely distributed in the upper Mississippi and Ohio Valleys, having been found in Iowa, Illinois, Missouri, Tennessee, and Indiana. As represented in the collections and based on field experience, the genus was most prolific, both as to number of species and individuals, in the Burlington. As reflected in the specific separations, this was likewise the time of maximum variability. Maximum size was reached in Keokuk time.

Besides the species here listed there are interesting new forms from horizons of approximately Keokuk age in Tennessee and Indiana. From Whites Creek Springs, near Nashville, Tennessee, there is a set of typical arms, as well as several dorsal cups. The largest of these cups has an approximate diameter of 25 mm. From the Borden group of Indiana, near New Ross, is a complete crown some 80 mm. in height and with a dorsal cup 25 mm. in diameter. In the upper Borden of Indian Creek, Montgomery County, Indiana, is a new species referable to *Eratocrinus*.

Relationships.—*Eratocrinus* resembles *Zeacrinus* superficially in the shape of the dorsal cup and in the possession of endotomous arm structures. The crown of *Eratocrinus* is elongate inverted pyriform, as against the ovate shape of *Zeacrinus*. The cup of *Eratocrinus* is relatively deeper than in *Zeacrinus*, being bowl-shaped rather than depressed basin-shaped. The arm facets in *Eratocrinus* are shallower than in *Zeacrinus* and are nearly horizontal as against the high-angled facets of *Zeacrinus*. The BB of *Zeacrinus* are typically elongate, the post B being disproportionally so. RA in *Zeacrinus* penetrates deeply between post and R post BB, meeting post B on a very narrow face, if at all. RA in *Eratocrinus* rests subequally on the upper sloping shoulders of post and r post BB. Anal x in *Eratocrinus* rests on the broad horizontal truncated distal face of post B. In *Zeacrinus* x either does not contact with post B, or when it does it usually rests on a very narrow oblique face. The arms of *Eratocrinus* are proportionally longer and more slender than in *Zeacrinus*. The ventral sac of *Eratocrinus* is elongate club-shaped as against broad-based pyramidal sac of *Zeacrinus*. Aside from formal differences a casual glance will serve to separate the dorsal cups, or sets of arms of the two genera.

I do not believe that *Eratocrinus* and *Zeacrinus* are nearly related. I conceive the ancestor of *Zeacrinus* to be an undescribed genus, the earliest known species of which is found in the Keokuk, and which is more unlike *Eratocrinus* than is *Zeacrinus*. Very young specimens of *Eratocrinus elegans* in general habit resemble *Zeacrinus* more than do the adults, though, of course, such details as the relative positions and shapes of the plates of the dorsal cup are quite unlike *Zeacrinus*.

Linocrinus, n. gen.

Genotype.—Linocrinus wachsmuthi, n. sp.

Generic diagnosis.—

Crown. Expanding gradually, then incurving distad.

Dorsal cup. Bowl-shaped, flattened and slightly invaginated at base. Plates typically rugose in adult stages.

IBB. Small, in central depression, concealed by column.

BB. Subequal, taking part in the flattened basal area, then flexing upward to help form the sides of the cup.

RR. Radial facet extending full width of R, suture gaping.

Anal plates. Three in cup. RA rests subequally on sloping shoulders of post and r post BB. Anal x rests on horizontal distal face of post B.

IBr. Three to five in ant. R, one in all others. The IBr_1 is sharply keeled.

Arms. Endotomous, except in anterior radius, which is isotomous as seen. Rami relatively stout, frequently with median longitudinal keels or nodose Br. In some species the Br of juxtaposed rami tend to interlock by lateral processes. Br quadrangular, but somewhat cuneate.

Ventral sac. In the type species extending to near the tips of the arms and turned back on itself in the distal portion.

Characteristic species of the genus.—

Linocrinus arboreus (Worthen), n. comb.

Zeacrinus arboreus Worthen, p. 534, pl. 20, fig. 5, 1875. "St. Louis limestone? near Huntsville, Alabama." (Probably Gasper formation of the Chester group, Monte Sano, east of Huntsville, Alabama.)

Poteriocrinus (*Pachylocrinus*) *arboreus* Wachsmuth and Springer, p. 116 (339), 1880.

Woodocrinus arboreus Wachsmuth and Springer, p. 242 (166), 1886.

Linocrinus asper (Meek and Worthen), n. comb.

Zeacrinus asper Meek and Worthen, p. 150, 1869.—Meek and Worthen, p. 430, pl. 1, fig. 7, 1873. "Upper division of Burlington group, Burlington, Iowa." (Lower Burlington)

Pachylocrinus asper Wachsmuth and Springer, p. 116, 1880.

Zeacrinus asper Wachsmuth and Springer, p. 128, 1880.

Woodocrinus asper Wachsmuth and Springer, p. 242, 1886.

Linocrinus cariniferous (Worthen), n. comb.

Zeacrinus cariniferous Worthen, p. 535, pl. 20, fig. 4, 1873, "St. Louis limestone? near Huntsville, Alabama." (Probably Gasper formation of the Chester group, Monte Sano, east of Huntsville, Alabama.)

Coeliocrinus cariniferous Wachsmuth and Springer, p. 133 (358), 1880.

Linocrinus compactus (Laudon), n. comb.

Zeacrinus compactus Laudon, p. 66, pl. 5, figs. 4, 5, 1933. "Gilmore City formation, Gilmore City, Iowa."

Linocrinus lautus (Miller and Gurley), n. comb.

Poteriocrinus lautus Miller and Gurley, p. 30, pl. 2, figs. 18, 19, 1896. "Keokuk group, at Booneville, Missouri." (Warsaw)

Linocrinus penicillus (Meek and Worthen), n. comb.

Scaphiocrinus penicillus Meek and Worthen, p. 142, 1869.—Meek and Worthen, p. 414, pl. 2, fig. 7, 1873. "Upper division of the Burlington group, at Burlington, Iowa."—Wachsmuth and Springer, p. 113 (336), 1880.

Linocrinus perangulatus (White), n. comb.

Zeacrinus perangulatus White, p. 11, 1862. "Upper division of the Burlington limestone, Burlington, Iowa."
Pachylocrinus perangulatus Wachsmuth and Springer, p. 116 (339), 1880.
Woodocrinus perangulatus Wachsmuth and Springer, p. 242 (166), 1886.

Linocrinus praemorsus (Miller and Gurley), n. comb.

Scaphiocrinus praemorsus Miller and Gurley, p. 48, pl. 8, fig. 11, 1890. "Keokuk group, in Washington County, Indiana."

Linocrinus scobina (Meek and Worthen), n. comb.

Zeacrinus scobina Meek and Worthen, p. 149, 1869.—Meek and Worthen, p. 426, pl. 1, fig. 2, 1873. "Upper division of the Burlington group, Burlington, Iowa."—Wachsmuth and Springer, p. 129 (352), 1880.
Woodocrinus scobina Wachsmuth and Springer, p. 242 (166), 1886.
Woodocrinus? *scobina* Springer, p. 147, 1911.
N. Gen. scobina, Springer, p. 148, 1911.

Linocrinus spinuliferus (Worthen), n. comb.

Poteriocrinus spinuliferus Worthen, p. 27, 1884.—Worthen, p. 86, pl. 14, fig. 3; p. 90, pl. 17, figs. 1, 1a, 1890. "Chester limestone near Columbia, Monroe County, Illinois."

Linocrinus wachsmuthi, n. sp.

Ste. Genevieve formation of the Chester group, about 7 miles south of Huntsville, Alabama.

Geologic and geographic distribution.—The genus *Linocrinus* as recognized at present extends from the Kinderhook to the Chester and has a geographic distribution coextensive with the Mississippian deposits. It seems to be one of the most ubiquitous of the Inadunate genera.

Relationships.—The norm for the genus is a line of small species that has a remarkable similarity of structure, form, and ornamentation from the earliest appearance of the genus to the end. The interrelationships of Linocrinus seem to be with *Decadocrinus* and *Pachylocrinus*. *Decadocrinus* with its rugose plates, keeled Br, and gaping suture seems to come nearest to *Linocrinus*. An endotomous *Decadocrinus* with a few minor changes would give *Linocrinus*, just as a *Decadocrinus* with two isotomous divisions above the main dichotom is essentially *Pachylocrinus*. From *Eratocrinus*, *Linocrinus* differs in the rugosity of the cup plates, its keeled Br, and its well-marked gaping suture between the R and IBr_1.

Linocrinus wachsmuthi, n. sp.

Types.—As types of the species I have chosen part of the specimens figured by Springer (1926) as illustrating "*Zeacrinus arboreus* Worthen."

As holotype I have chosen the specimen illustrated as figure 5, plate 16, and as paratypes the specimens illustrated as figures 4 and 6 on the same plate. The types are in the Springer collection in the United States National Museum. The genotype is dedictated to Charles Wachsmuth, to whose tireless efforts in the field and study we owe a great part of our knowledge of American crinoids. The specimens chosen as types were collected by him and his wife.

Description.—The species has a small, compact crown expanding somewhat distad. The dorsal cup is basin-shaped with a flattened base. The plates of the cup are rugose, the surface ridges falling into definite but interrupted patterns. Ridges extend from center to center of the BB and from the centers of the BB across on the RR. There is usually a well-defined median, vertical ridge on each radial.

The IBB are small and concealed by the column. The BB are large, taking part in the flattened basal area, and flexing upward to form part of the sides of the cup. The RR are large with a straight articulating facet extending the full width of the radial. The suture with the IBr is broadly gaping.

There are from 4 to 5 IBr in the ant. R, the first primibrach being very large. In the other rays there is but one IBr to the ray. The first primibrach is traversed by a median vertical keel. The arms are relatively short, stout, and endotomous. Two divisions above the main dichotom are usual. The Br to the second division are usually traversed by a longitudinal keel. The Br are quadrangular, with a slight taper in the lower portions of the arm. Distad the Br are cuneate. Laterally there may be spinous processes that tend to interlock with similar processes on juxtaposed rami.

The ventral sac is somewhat shorter than the arms, reflexed in the distal portion, and with three rather prominent, median rows of plates that tend to be spinous.

Horizon and locality.—The main locality for *Linocrinus wachsmuthi* is about seven miles south of Huntsville, Alabama, near the foot of the ridge east of the road. They occur in the Ste. Genevieve formation of the Chester group. Having been at the type locality with Mrs. Wachsmuth I am able to give a locality somewhat better than the stereotyped "Huntsville, Alabama."

Relationships—From *Linocrinus cariniferous* (Worthen) and *Linocrinus arboreus* (Worthen) from stratigraphically higher beds of the same region, *Linocrinus wachsmuthi* can be distinguished most readily by the greater rugosity of the cup-plates, the plates of the later species being tumid with depressions at the angles, or with obscure, rounded ridges. Worthen's type of *Linocrinus arboreus* is either a young specimen or a small species. There are no marked juvenile characters in the specimen, judging from casts of the type, but it may well be the young of *L. cariniferous*. The arms of *L. arboreus* are relatively stouter than in *L. wachsmuthi*, and the Br are almost rectangular in outline, despite the original figure. The dorsal cup of *L. arboreus* is relatively much higher than in *L. wachsmuthi*.

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BOTANY.—Raouliopsis (*Asteraceae*), *a new genus of "vegetable sheep" from the high páramos of Colombia.*[1] S. F. BLAKE, Bureau of Plant Industry.

The "vegetable sheep" of New Zealand—species of *Haastia* and *Raoulia*, genera belonging to two different tribes of Asteraceae—are among the oddities of the vegetable kingdom. The repeatedly branched stems, only a few inches or sometimes a couple of feet high and about as thick as the finger with their dense covering of linear to cuneate, densely pilose, many-ranked, long-persistent leaves, are compacted into convex or flattish, rounded or amorphous, brownish or greenish cushions, sometimes as big as an ordinary sofa and so dense that the point of a pencil or "even of a pin" cannot be thrust between the branches.[2] The small or medium flower heads, in both genera lacking rays but provided with filiform pistillate florets, are borne singly[3] at the tips of the branches, sunken among the leaves and almost hidden by them. The extreme compactness of the plants and their dense covering of hairs are obviously correlated with their habitat, bare rocky hill slopes at about 40° S. latitude, where the hot dry winds of summer and the winter's snows, low temperatures, and violent gales expose them to a perpetual alternation of desert and arctic conditions. These extreme modifications of structure, however, are specific rather than generic, and are shown by only about 9

[1] Received January 6, 1938.

[2] According to E. Low, Trans. N. Z. Inst. **32**: 151. 1899, in her account of the vegetative organs of *Haastia pulvinaris.*

[3] Or, in a single variety (*Raoulia grandiflora* var. *fasciculata* (J. Buch.) Cheesem.), in 3's.